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APPLICATIONS WORKSHOP III-A-2

INSTRUMENTATION

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INTRODUCTION

Several inherent features of the rolamite concept look particularly inviting for instruments. The means of amplification, the gravity and inertial balancing techniques, the low friction, generation of selected forces, and the capability of matching inputs and outputs of various shapes and forms are all applicable to various instruments.

Specific interests of participants in the workshop included applications as dial indicators, miniature inertial devices, tape-recorder devices, low pressure transducers, rotary switches, aircraft part instrumentation controls, dimensional gages and industrial timing and control mechanisms.

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SENSING PRESSURE

Discussion began on the general topic of using rolamite to sense pressure, with the general guidelines that 5 percent variations in the band are likely to produce errors which become important at low pressures. Chairman Gladow pointed out, "Assuming that you wish to use the rolamite band as a spring, at low pressures you're probably also considering very small sizes. It should be mentioned that the smaller sizes become increasingly dependent on contaminants in the system and on the properties of the band materials."

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HOLLOW TUBE SENSOR

One way of using rolamite as a pressure transducer is fabrication of the band as a hollow tube. This technique avoids the need for close-fitting side plates, required in the usual rolamite fluid system. Using the cluster as a piston obviously cannot provide a perfect seal because of leakage past the ends of the rollers. On the other hand, a preformed tubular band can provide an excellent seal.

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PRODUCING PISTON-TYPE SENSORS

Sandia has not attempted to obtain perfect sealing in using the roller cluster as a piston, but minimizes the flow past the rollers so that it becomes insignificant as compared to that through a sharp edge orifice. In devices measuring about an inch and a half in length, clearance is down to a half a mil or smaller. With this clearance, the viscous forces become large and the flow is very small; typical flows are 0.0001 cubic inch per second.

Manufacturing the rolamite case has been one of the main problems in trying to minimize clearances, with the best method that of vacuum drawing glass. The technique achieves dimensional accuracies of ±0.0002 inch, but ±0.0004 or ±0.0005 is more typical. In

ODOMETERS

Mr. David Overman, Harry Diamond Laboratories, indicated that he was interested in the rolamite geometry for use in odometers. He asked for comments on increasing the scale factor of odometers by the use of rolamite. Elmer Leslie, Sandia Laboratories, pointed out that rolamite geometry can provide a higher speed ratio, with only one set of rollers, than can be provided by a single stage of gearing. Second, in an inertial odometer, inertial loads on bearing-mounted mechanisms can cause high and variable frictional losses. However, a rolamite odometer does not require placing bearings in the acceleration field. Some work on odometers performed at Sandia Laboratories showed that a rolamite odometer using only one set of rollers could provide a scale factor of 1 inch of roller travel corresponding to 2.7 miles of vehicle travel.

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ROLAMITE MECHANISM PROPERTIES

Mr. Heinz Runge of National Dairy Products Corporation asked if anyone had used rolamite with timing belts for bands and gears for rollers, etc. His company was interested in using rolamite as a mechanism in high-speed packaging machinery. His interest was mainly concerned with unique motions afforded by rolamite rather than the low friction aspects. It seems that rolamite mechanisms might simplify some of the machinery, thereby reducing costs. No one at the workshop had used rolamite in this manner. Even so, the panel agreed that it was valid to consider rolamite more for its mechanism properties than for its frictional properties.

vacuum drawing, a mandrel of the desired cross section is placed inside a round glass tube. One end of it is sealed off and a vacuum is drawn on the other end. With the application of heat, the glass is drawn onto the material. Since the coefficient of expansion of the mandrel, which is typically stainless steel, is larger, it will shrink away for removal. Because it will seal with Kovar, 7052 glass is used.

In the finished devices a spring-loaded bar is mounted so that when the rollers pass by it, it will spring up. If the glass case breaks, it provides a fail-safe arrangement.

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EFFECT OF WEAR-IN

Rolamite has a tendency to "wear-in." Dean Gladow discussed measurement of wear-in as it affects force generation variations. Most of the information available involves roller sizes of 3/8 and 1/2 inch. For these, force variations are typically about 2 to 3 percent. For example, a band with a rectangular cutout in it should theoretically produce a force deflection curve which is a step function existing for a given distance. However, experimental testing reveals two important deviations: a rounding of the corners, and a jaggedness (or noise). The jaggedness is somewhat reduced with repeated traverses of the roller cluster. Typically, the total friction might be reduced by about 20 percent after 50 traverses. Interestingly, after the repeated traverses, the jagged pattern will still be quite recognizable with the high points still at the same place. This indicates very good re-matching with little, if any, slippage of the roller with respect to the band.

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EFFECT OF GUIDE RAILS

In many applications, rolamite requires a guide rail, but there are ways of avoiding them. If the total motion is less than one wetted perimeter of the roller, the band can pin directly to the roller. Secondly, if side loads are small as compared to the normal force produced by the band tension, rails are not necessary.

But rails can be designed so that the additional friction is very low. The analysis of friction due to the side rails has to be done on an energy basis. A point on the end of a roller which is close to the point of contact between the roller and the flat surface has a very small instantaneous velocity. Therefore, if a side rail is to be used, its height should be kept small as compared to the roller diameter so that the area of contact is in the zone of small velocities. If this condition is met, the energy loss and coefficient of friction will be small. A typical rail height 1/30 of the roller diameter will provide quite high side-load carrying capability.

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EFFECT OF BAND SLIPPAGE

Macroslipping or actual visual slippage between the rollers and band depends on band tension. Less is known about preventing or analyzing microslippage, or creep. As Chairman Gladow pointed out, all slippage can be prevented by attaching the band physically to a roller by riveting, pinning, or spot welding--when motion is restricted to less than one wetted perimeter. "If this is not possible or desirable, the possibility of macroslippage can be analyzed to a first approximation by use of the basic bolting formula, $T_1/T_2 = e^{\mu\beta}$, where T_1 is the tension on the tight side, T_2 is the tension on the loose side, μ is the coefficient of friction, and β is the wrap angle. In rolamite, we have a better situation than in normal belting systems because of larger wrap angles. By inspection of the rolamite geometry, it can be seen that the wrap angle has a minimum value of 180 degrees and a maximum value of 270 degrees. Use of this formula will provide a first approximation of the tension required to prevent slippage. To be exact, it would also be necessary to consider the flexural strength of the band which tends to decrease total friction. For a given application, knowledge about expected inertial loads and/or torques which might be applied to the system can be used to determine the difference in tension on the tight and slack sides. Use of the belting formula then allows the calculation of the required initial tension. Work remains to be done on the subject of microslippage."

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MINIMUM BAND WIDTH

Minimum width for rolamite bands is dependent on the overall size of the unit, but the determining factor of band width is usually the requirement of alignment. Obviously, use of a wide band and small diameter rollers leads to a strong tendency for alignment. As discussed, the normally strong alignment tendency in a rolamite is an important factor in low friction characteristics. Therefore, the required frictional behavior as well as any loading which might tend to disturb the alignment must be considered. Narrow band alignment could be provided by interaction of the rollers and guide rails. If this were done, a very narrow band could be used, although the rollers would still have to be of sufficient length for adequate alignment. This method could be particularly effective if each roller surface were provided with a groove which was just deep enough to accept the band. The ends of the rollers would then contact each other as well as the guide surface to provide the alignment.

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WIRE TO REPLACE BAND

The workshop proposed that a band could be made by using two wires. Each would operate in a groove near the end of the roller to provide good alignment. The diameter of the wire would have to be small to avoid yielding; essentially, the diameter could be no larger than the maximum thickness of a band made of the same material.

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ACCURACY OF BAND CUTOUTS

In reply to a question about predicted and actual generated forces, Chairman Gladow explained some of the assumptions of the theoretical analysis. "The simplified formula predicts the force to be:

$$F = \frac{E t^3 (a-b)}{6d^2}.$$

PREDICTIONS

One usual assumption is that Young's modulus, E, is the classical textbook value. More accurately, the "plate modulus" should be used since the band width is typically very large compared to its thickness. The plate modulus is

$$\frac{E}{1 - \nu^2}$$

where ν is Poisson's ratio. Also, the roller diameter, d, should be increased by approximately the thickness of the band, or even more exactly, by twice the distance from the roller surface to the neutral stress plane of the band. The simplified formula also assumes that the band was initially flat and that the cutout is present only at one roller contact point. I refer you to Dr. Cadman's paper for a thorough analysis of rolamite force generations. His generalized equations can be used to determine the effect of band thickness changes, variations in Young's modulus, precurved bands, and cutouts at all inflection points. However, we find that the simplified formula is usually sufficiently accurate and complete enough to do preliminary design. In fact, we can usually build prototype units without referring to the generalized equation."

CALCULATIONS

Sandia makes use of the generalized equation through computer design. Cadman's computer programs for force equations can obtain a complete force profile for a given geometry. At this point, however, one cannot define a force function and have the computer define the design parameters.

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SPECIAL CUTOUTS

Since large cutouts in the band often create problems (for example, with spool rollers), they may be avoided in two ways: One is the method that Hamilton has used, in which the bands are etched only part way through. This method is quite effective since the generated force is proportional to the cube of the thickness. Therefore, if one-half of the material thickness is removed by etching, the remaining thickness has only one-eighth of the original flexural strength. Therefore, the depth of etching usually need not be controlled to any high accuracy. A second method of maintaining band integrity is to produce the desired bank weakening by etching a screen pattern into the band instead of a complete cutout.

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ACCURACY OF PRECURVED BANDS

In approximate performance force generation, precurved bands may often be used, but in general cutouts are recommended to control force generation to a precise level. However, heat treating on a mandrel can provide precurved shapes which have much more controlled behavior than cold-formed bands. Hamilton's experience with preformed shapes other than coil springs indicates that production techniques are available to the state of art required for many preforming applications.

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DAMPING CLUSTER MOTION WITH VISCOUS LAYERS

Damping fits well into the general field of instruments. One method of damping involves including viscous material between a sandwich band. If this method is used, damping is almost independent of roller diameter.

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SHARP ORIFICE DAMPING

Another method of damping uses the cluster as a piston, to force a fluid through an orifice. Bruce Hodgins (SL), explained that Sandia's "pumper units" were based on this principle. A sharp-edged orifice in the band makes timing independent of temperature. The rollers, relatively long but of small diameter to reduce leakage past the ends, are in the cross-bar of a T-shaped case. The vertical leg of the T serves as a return path for the fluid. This unit is also provided with electrical contacts for switching, in an overall size typically 1/2 by 3/4 inch or 1-1/2 by 2 inches. The fluid is a silicon oil very temperature-stable in viscosity.

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EFFECTS OF ACCELERATION

Rolamite assemblies can be balanced against acceleration in both linear and rotary modes, and remain balanced regardless of frequency and/or level. Departures from balance would be second-order effects--for example, with a loose geometry the rollers would have a slight linear motion without any motion relative to the band. Linear is due to the translation of the roller cluster; rotational is due to the rotation of the rollers. The rotational inertia is proportional to the square of the radius of gyration. Therefore, the inertial behavior of a rolamite unit can be changed considerably by changing the radius of gyration (most simply by changing the roller diameter size). On the other hand, a high inertial system with light weight can be constructed using tubular rollers. A low inertia system can be effected by using spool-shaped rollers.

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SENSITIVITY TO LINEAR AND ROTARY ACCELERATION

For a device sensitive to linear acceleration but not to rotary, the rollers should have the same rotational inertia, which is most easily accomplished by making them identical. The unit is completely insensitive to rotary acceleration around the point where the rollers contact. To make a unit sensitive to rotary but not to linear acceleration, counterbalance one roller only and not both.

ROLLER SIZE EFFECTS

Different sized rollers in a rolamite are obviously valuable because of differing speed ratios, but a second advantage is the variation of inertial behavior. A system of much higher rotational inertia results if a large roller is used in conjunction with a small one. A third advantage is that the force being generated is proportional to the square of the diameter. Therefore, the force produced by a given band can be widely varied by using different size rollers.